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ANALYSIS TECHNIQUES
FOR
A-7D AIRCRAFT
IN-FLIGHT RECORDER DATA

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AEROSPACE STRUCTURES
INFORMATION AND ANALYSIS CENTER

OPERATED FOR THE AIRFORCE FLIGHT DYNAMICS LABORATORY
BY ANAMET LABORATORIES, INC.

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Information and Analysis Center*

AEROSTRUCTURES IAC
ANAMET LABORATORIES, INC.
100 INDUSTRIAL WAY
SAN CARLOS, CALIFORNIA 94070
TEL. (415) 593-2128

AEROSTRUCTURES IAC
AFFDL/FBR
WRIGHT-PATTERSON AFB,
OHIO 45433
TEL. (513) 255-6688

This report summarizes the planned method of analysis of the A7D flight loads data collected by multi-channel recorders. The verified results will then be used to produce exceedance curves and histograms. This work was the preliminary step in a complete analysis of data to be conducted at a later date.

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Submitted by:

Michael R. James

Michael R. James

Approved by:

Conor D. Johnson

Conor D. Johnson, Ph.D.

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I. INTRODUCTION

This effort was conducted to study the techniques necessary to analyze A-7D flight loads data collected at Davis-Monthan AFB, Arizona, Selfridge Air National Guard (ANG) Base, Michigan, and Toledo ANG Station, Ohio, by Mr. David L. Banaszak, AFWAL/FIBG, using multi-channel flight loads recorders. Three axis accelerations, three axis rotations, altitude, and airspeed were recorded on tape magazines as shown in Table 1. These magazines were then sent to Wright-Patterson AFB where the Structural Vibration Branch (FIBG) of the Flight Dynamics Laboratory condensed the raw data on standard 9-track computer tapes. At this point the Aerospace Structures Information and Analysis Center (ASIAC) was contacted to examine the data and to consider reducing this data into a form suitable for presentation in a technical report.

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TABLE 1
OUTPUT DATA SYMBOL AND UNITS

SYMBOL	DEFINITION	UNITS
A	Altitude	Feet
V	Velocity	Knots
X	X acceleration N_x	g's
Y	Y acceleration N_y	g's
Z	Z acceleration N_z	g's
P	Roll	Degrees per sec.
Q	Pitch	" " "
R	Yaw	" " "
Time	Time	1/30 second
I	Two or more of the above listed data points falling in the same band	

II. EXPLANATION AND INTERPRETATION OF THE DATA

Table 2 gives a listing of the 9-track computer tapes and their contents. These contents are data files which were created by compressing the raw data from the in-flight recorder magazines. This raw data was condensed by using a computer program written by FIBG (Structural Vibration Branch) WPAFB, Ohio. Table 2 goes on to note which of the tapes listed are usable and to what extent they are usable.

A particular raw data tape is one magazine from one in-flight recorder. This raw data tape then comprises one file on the condensed data tape. Each file is a monitoring of one aircraft for the length of time that the in-flight recorder was in use on this aircraft, so each file may contain many flights.

The computer program LCOMP, written by FIBG, was used to scan each compressed data tape and print output tables with one of the following options:

- (1) A tabular listing of altitude, airspeed, accelerations in the x, y, and z directions, roll pitch, yaw and time.
- (2) A graphical representation of the above parameters.
- (3) Both a tabular and graphical representation of the above parameters, as shown in Table 3.

The computer program LCOMP scans each data tape and prints the following output in order:

- (1) Identification data - data used to identify the aircraft, base, etc.
- (2) Engineering units - this is a table of values which creates 64 bands for each parameter (altitude, airspeed, acceleration in x, y, and z directions, roll, pitch, yaw, and time.)
- (3) Output selection by option:
 - (a) A tabular listing of each parameter.
 - (b) A graphical representation of each parameter
 - (c) Both tabular listing and a graphical representation of each parameter.

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TABLE 2

LISTING OF TAPES

TAPE NO.	CONTENTS	USABILITY (If Bad; Reason Bad)
X01061	11 Files	All Files Usable
X02560	6 Files	All Files Usable
X00185	6 Files	5 Files Good (Bad file due to incomplete file)
X02980	9 Files	All Files Good
X03327	9 Files	All Files But 2 Good (2 files only partial)
X03499	8 Files	All Files Bad (Data very inconsistant)
X04143	8 Files	All Files Bad (Tape unable to be read without parity errors)
X00872	7 Files	All Files Bad (Data inconsistant)

TABLE 3. TYPICAL LCOMP OUTPUT

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The identification data presents information concerning aircraft tail number, squadron, base, number of flights, aircraft gross weight at takeoff, and recorder magazine number. This data is used to identify the aircraft from which the data came. Calibration data is also included as shown in Table 4. This is used in the calculations of flight times and for the creation of the 64 bands for each parameter, i.e., airspeed, time, altitude, etc. The remainder of the data would primarily be beneficial to the maintenance crew for that specific aircraft.

The next output from LCOMP is shown in Table 5. This output shows the specific value for each parameter in each band; e.g., average altitude is 424.93 ft. in Band 1, and 856.58 ft. in Band 2. The parameters are defined in Table 1, with the exception of PA, atmospheric pressure, and QC, dynamic pressure, both in inches of mercury. All units in Table 5 are shown times 1000 except for altitude and velocity. For example, PA = 20920 is actually 20.920 in. of mercury. Altitude (ALT) is in units of feet, and velocity (VCAL) is in units of knots. The column labeled COUNTS is actually the band number, varying from 0 to 63. This number corresponds to the number shown on the tabular portion of the output (see Table 3) and positions the parameter's appropriate symbol in the appropriate position in the graphical output to the right, as shown in Table 3.

The last portion of output from the program LCOMP is the tabular and graphical representation of the data. All symbols are shown and explained in Tables 1 and 5, with a typical example of output in Table 3. Table 3 shows the option of both tabular and graphical representation of the data. The first 8 columns (tabular chart) list the band that each of the eight parameters falls into. The ninth column is the time represented in 1/30's of a second. The 64 columns following

TABLE 4
IDENTIFICATION DATA

FILE#	1	TAIL SWI	WING	MAG	MEL	ACL	GYK	PIX	DATA/16	DATA/32	DATA/64	DATA/128	DATA/256	DATA/512	DATA/1024	DATA/2048	A/LINHIS1	A/LINHIS2	ECTC1	ECTC2	TCFC1	TCFC2	U.S.1	U.S.2	EXTRA
00014	325	1	16	13	2	1	2	120177	260177	236177	1	10	1	10064	10064	1	2396	2396	1	1	1	1	0	0	0
FLII	WING	16	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
1	1	638	1401	26852	1	1	1	1725	1401	22080	20	20	20	20	20	20	20	0	0	0	0	0	0	0	0
2	1	1525	1401	24934	1	1	1	1151	1601	22086	20	20	20	20	20	20	20	0	0	0	0	0	0	0	0
3	1	1013	1601	24939	1	1	1	1700	1601	22089	20	20	20	20	20	20	20	0	0	0	0	0	0	0	0
4	1	1525	1601	24957	1	1	1	1024	2001	22452	50	50	50	50	50	50	50	0	0	0	0	0	0	0	0
5	1	820	2001	28752	1	1	1	1716	2001	23652	30	30	30	30	30	30	30	0	0	0	0	0	0	0	0
6	1	1540	2001	28152	1	1	1	1715	2101	22136	20	20	20	20	20	20	20	0	0	0	0	0	0	0	0
7	1	1535	2101	29664	1	1	1	1715	2101	22136	20	20	20	20	20	20	20	0	0	0	0	0	0	0	0
8	1	1405	2401	28152	1	1	1	1610	2401	21652	40	40	40	40	40	40	40	0	0	0	0	0	0	0	0
9	1	1002	2501	27752	1	1	1	1210	2501	21852	40	40	40	40	40	40	40	0	0	0	0	0	0	0	0
10	1	410	2601	26854	1	1	1	1050	2601	21946	20	20	20	20	20	20	20	0	0	0	0	0	0	0	0
11	120	95	95	120	98	100	125	134100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
*All identification data																									
458	071	190	08	-5b	11249	1693	190600	29920	657	-5125	-2296	1755	-501260	-60364	-60364	-60364	-60364	-60364	-60364	-60364	-60364	-60364	-60364	-60364	-60364

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TABLE 5. ENGINEERING UNITS OF EACH DATA BAND

the tabular chart are a graphical representation of the same data, plotted with the parameter symbols shown in their band position. That is, altitude (A) = 6 and yaw (R) = 8 causes "A" to be printed in column 6, and "R" in column 8. The step increments used throughout the tabular or graphical output is based on time in 1/30's of a second. The output only prints when a specific item changes bands. All data not displayed between several time steps can be assumed to remain within the last band shown until the output is printed again. The values for the parameters can change between printed lines as long as the values remain within the bands and do not exceed a threshold value that will put them into the next band.

III. ANALYSIS OF THE DATA

Eight tapes containing 64 files with collected flight loads data from 84 magazines were examined. All of the compressed data was run through the program LCOMP and then viewed by hand to determine its true validity.

Some data was determined to be unreasonable for several reasons. A short list of examples follows:

- (1) There should not be any altitude jumps in the graph for a short period of time. Altitude should usually only change one band in 1/30th of a second.
- (2) Straight and level flight should yield very little variation in roll, pitch, and yaw.
- (3) All data elements must be in the chart for the chart to be considered valid.

Tables 6 and 7 show typical examples of bad data. Table 6 shows a drastic jump in altitude from band 6 to band 62. During the short period of time involved (2/30 second), the altitude could not possibly jump from 3,100 feet to 66,845 feet. As a result, this section of data is not usable. N_x acceleration of the aircraft also shows a corresponding jump from band 30 to band 62. This jump in data appears to be caused by a transient voltage as the recorder is being shut down and then turned on again approximately three minutes later. From this point on, N_x remains in band 62, indicating that the aircraft is decelerating at a constant 1.841 g. The remaining channels of data appear constant and can be assumed to represent valid data, except for N_z . Additional analysis shows N_z to vary from band 31 to band 62, representing a vertical acceleration ranging from 2.755 g to 9.027 g, typically averaging around 4.0 g. Since altitude remains in band 6, representing 2,640 feet, these values of N_z do not appear valid and this entire section of data must be discarded.

TABLE 6. EXAMPLE OF ERRONEOUS DATA

TABLE 7. EXAMPLE OF ERRONEOUS DATA

Table 7 shows a pattern of constantly changing altitude, which suggests that the aircraft is going through a maneuver. Careful examination of the data shows that the altitude changes by 1385 feet in 1/30th of a second, which is not possible; and again all of this data must be eliminated.

After analyzing all the 9-track compressed data tapes it was determined that the earlier test flights yielded the best data. During later flights, many channels of output data were found unusable. Instrumentation errors along with flight recorder upkeep were apparently the cause for this unusable data. The first channel of data to deteriorate was altitude, and this is the most serious loss of data.

Despite the amount of invalid data, the data tapes appear to contain sufficient usable A-7D flight loads data so that data reduced in this effort will reflect A-7D usage accurately.

A primary difficulty to be encountered when reviewing all data tapes is that the calibration data varies from recorder to recorder. Deciding upon a common set of bands for each parameter is necessary to consolidate the data into a large file of usable information.

Histograms of time in bands for vertical load factors, altitude, and airspeed can be prepared and exceedance curves of load factors and roll rates can be established. Meaningful correlation tables of the various parameters are possible as shown in Table 8. However, because of the loss of some of the data, particularly altitude, there is insufficient data to produce some of the correlations. The most important correlations or cross-correlations are usually N_z with other parameters that affect calculations of aircraft loads. For example, simultaneous peaking of N_z and roll create asymmetric wing loading. Other correlations are possible, but probably not as meaningful.

A great deal of manual analysis and interpretation will be required to eliminate faulty data, in order to insure that the data used in the analysis is valid.

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TABLE 8
 MATRIX OF POSSIBLE MEANINGFUL CORRELATIONS

PEAKING PARAMETER	CORRELATIONS					
N_z	$N_z \cdot N_y$	$N_z \cdot Q$	$N_z \cdot P$	$N_z \cdot R$	$N_z \cdot A \cdot V$	
N_y	$N_y \cdot N_z$	$N_y \cdot Q$	$N_y \cdot P$	$N_y \cdot R$	$N_y \cdot A$	
PITCH (Q)	$Q \cdot N_z$	$Q \cdot N_y$	$Q \cdot A$			
ROLL (P)	$P \cdot N_z$	$P \cdot N_y$	$P \cdot A$			
YAW (R)	$R \cdot N_z$	$R \cdot N_y$	$R \cdot A$			